MIND WAVES
EDTECH
Ride the Knowledge

ATOMIC PHYSICS

WITH HAND WRITING
BOOKS FROM R.K'S SIR
IIT KANPUR

JEE/NEET/ADVANCED

27/07/2024 (Sat):- L:-7

ATOMS

Imp.Q = 4m + 2m = 3m + 2m = 4m
IIT JEE = 8m (or) 4m
IIT Adv = 9% to 12%

* Dalton's Theory :-

> According to Dalton's atomic theory atom is the smallest particle in matter. No particle can exist smaller than atom.

> It is electrically neutral ✓

> The fundamental particles of the matter remains constant and atom is the fundamental particle in matter.

> Different different materials has different different atomic size. (varies in the size of atoms.)

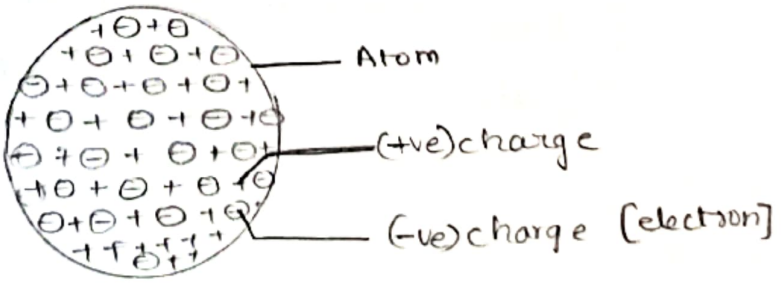
> According to modern sub-atomic theory, the atom consists electrons, protons, neutrons and elementary particles.

* J.J. Thomson's model :-

> First atomic model proposed by the J.J. Thomson.

> According to J.J. Thomson atomic model the atom posses a spherical shape. The (+ve) charge spread uniformly entire its volume and $e^{\ominus}$'s emitted (embedded) inside the (+ve) charge. It is electrically neutral. → watermelon model.

> According to atomic model, the atom is like a watermelon as show in figure.



plum pudding model.

* Drawbacks :-

> J.J Thomson atomic model couldn't explain stability of atom.

> Atomic model could not explain Rutherford α-scattering exp.

> He could not explain discreet spectral lines in Hydrogen atom.

(VVI) Definite (Q)

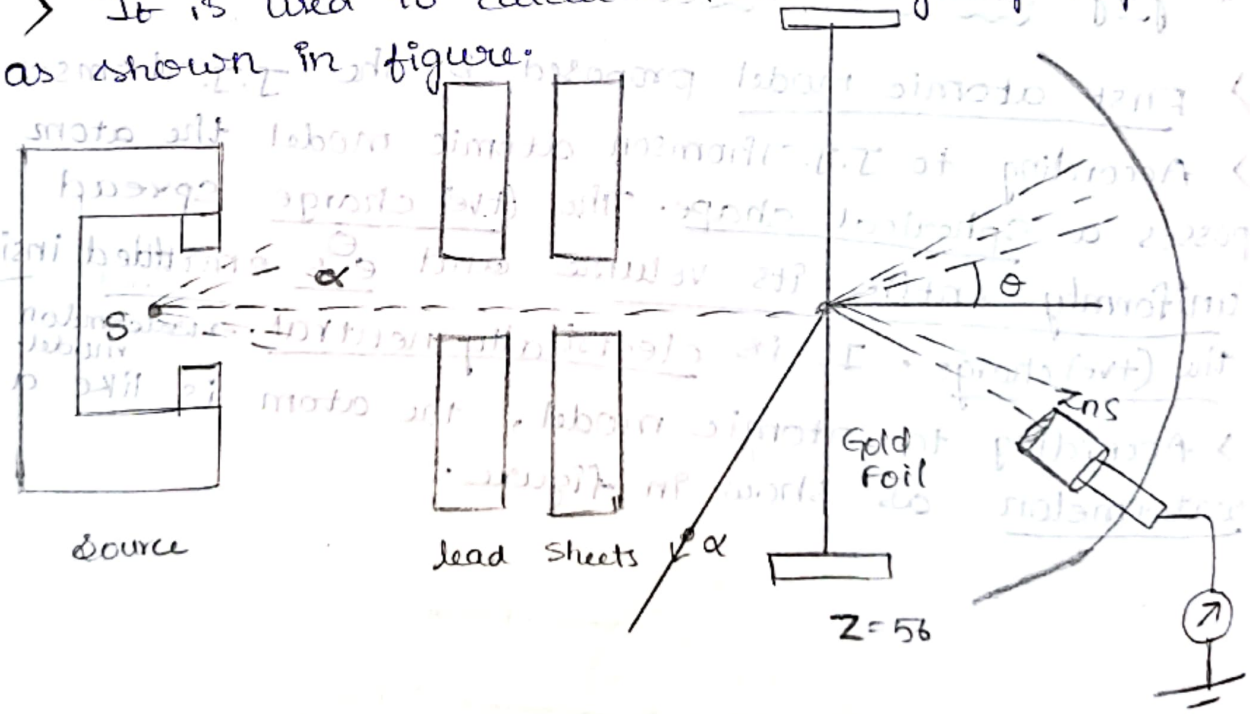
* Rutherford α-scattering experiment :-

[Geigar - marsden Exp.]

> This exp. consists radioactive substance act as a source. It emitts α, β and γ-rays which are moving very high energy (nearly 5.5 million e V).

> α-particles passes through the lead brick and strikes on gold foil. A travelling microscope arranged other side of the gold foil along with ZnS screen.

> It is used to calculate scattering of α-particles as shown in figure.



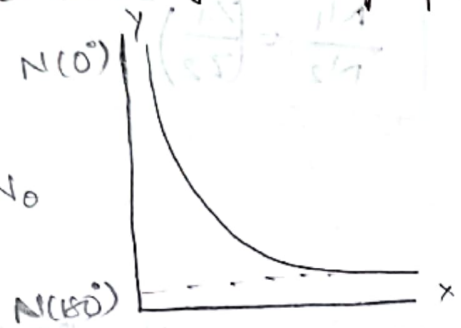
• Observations :-

→ According to Rutherford α-particle exp, most of α-particles scattered through Gold foil. The atom is completely empty.

→ 1 : 8000 α-particles are scattered more than 90°. It has very high energitic α-particle as shown in figure.

29/07/2024 (Mon) :-

> A graph drawn b/w no. of particles on y-axis and angle of scattering on x-axis. It represents the nature of the graph as shown in figure.



* From the exp. no. of α-particles scattered through the gold foil

$$N = \frac{Qnt z^2 e^4}{(8\pi\varepsilon_0)^2 r^2 \epsilon^2} \times \frac{1}{\sin^4(\theta/2)}$$

Q → Total no. of α-particles
n → no. of atom per unit volume
t → thickness of gold
z → Atomic number gold
r → distance b/w gold foil and ZnS screen.
ϵ → Kinetic energy of α-particle
θ → Angle of scatter.

* Note:

① $N \propto \frac{1}{\sin^4(\theta/2)}$

$$\frac{N_1}{N_2} = \frac{\sin^4(\theta_2/2)}{\sin^4(\theta_1/2)}$$

② $\frac{N}{t} = \text{constant}$

$$\frac{N_1}{N_2} = \frac{t_1}{t_2}$$

③ $N \propto \frac{1}{r^2}$

$$\frac{N_1}{N_2} = \left(\frac{r_2}{r_1}\right)^2$$

④ $N \propto \frac{1}{\epsilon^2} \cdot \propto \frac{1}{\left(\frac{1}{2}mv^2\right)^2}$

$N \propto \frac{1}{v^4}$

$$\frac{N_1}{N_2} = \left(\frac{v_2}{v_1}\right)^4$$

⑤ $N \propto Z^2$

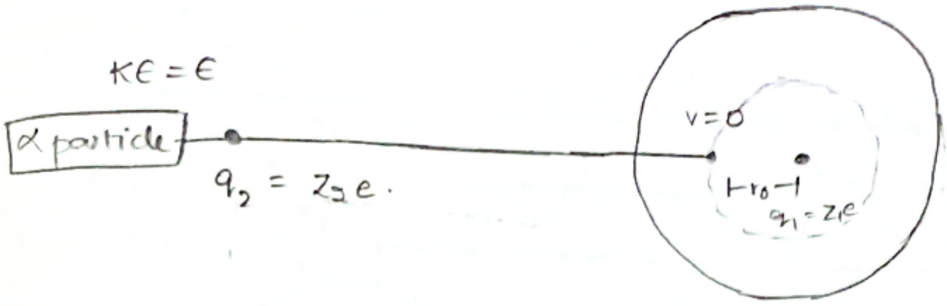
$$\frac{N_1}{N_2} = \left(\frac{Z_1}{Z_2}\right)^2$$

* According to rutherford's α-scattering exp atom is completely empty at the centre total mass of the atom concentrate at the centre it is high density particle and +ve charged particle. It is called Nucleus.

→ The size of the atom 10^{-10} m and the size of the nucleus 10^{-15} m.

* DISTANCE OF CLOSEST APPROACH :-

> Let a high energitic α-particle moves towards the nucleus or target element the K.E of the α-particle converted as a potential energy due to repulsive force b/w the α-particle and target element (gold foil)



r_0 = Radius of the nucleus.

› According to law of conservation of energy:

$\Delta KE = \Delta PE$

$$E = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r_0}$$

$$E = \frac{1}{4\pi\varepsilon_0} \frac{z_1 z_2 e^2}{r_0}$$

* The radius of Nucleus

$$(r_0) = \frac{1}{4\pi\varepsilon_0} \frac{z_1 z_2 e^2}{E}$$

› For α-particle ($_2He^4$)

$q_2 = z_2 e \Rightarrow q_2 = 2e$

$q_1 = z_1 e = ze$

$$r_0 = \frac{1}{4\pi\varepsilon_0} \frac{(ze)(2e)}{E}$$

$$r_0 = \frac{1}{4\pi\varepsilon_0} \frac{2ze^2}{E}$$

$E \rightarrow KE$.

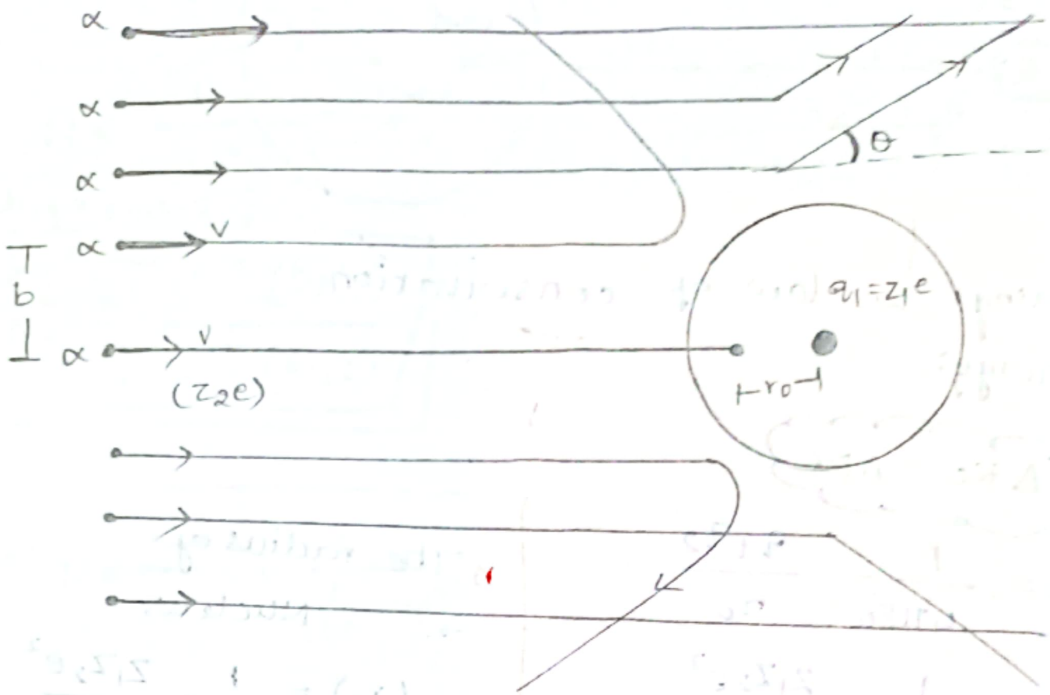
(VVI) Pacca (Q). Mains & Adv.

* IMPACT PARAMETER (b) :- (VVI) * *

› The shortest distance b/w velocity vector to centre of the nucleus is called impact parameter.

› It is represented by 'b'

* If impact parameter is maximum angle of scattering is minimum.
* If impact parameter is minimum angle of scattering is maximum.



From the experiment:

$$\cot(\theta/2) = \frac{2b}{r_0}$$

closest approach (r_0) =

$$= \frac{1}{4\pi\varepsilon_0} \frac{z_1 z_2 e^2}{E}$$

; $z_1 = ze$, $z_2 = 2e$

$$r_0 = \frac{1}{4\pi\varepsilon_0} \frac{(ze)(2e)}{\epsilon}$$

$$\cot(\theta/2) = \frac{2b}{\frac{1}{4\pi\varepsilon_0} \frac{2ze^2}{\epsilon}}$$

$$b = \frac{ze^2}{4\pi\varepsilon_0 \epsilon} \cot(\theta/2).$$

* Note :-

→ b is max. then angle of scattering min.

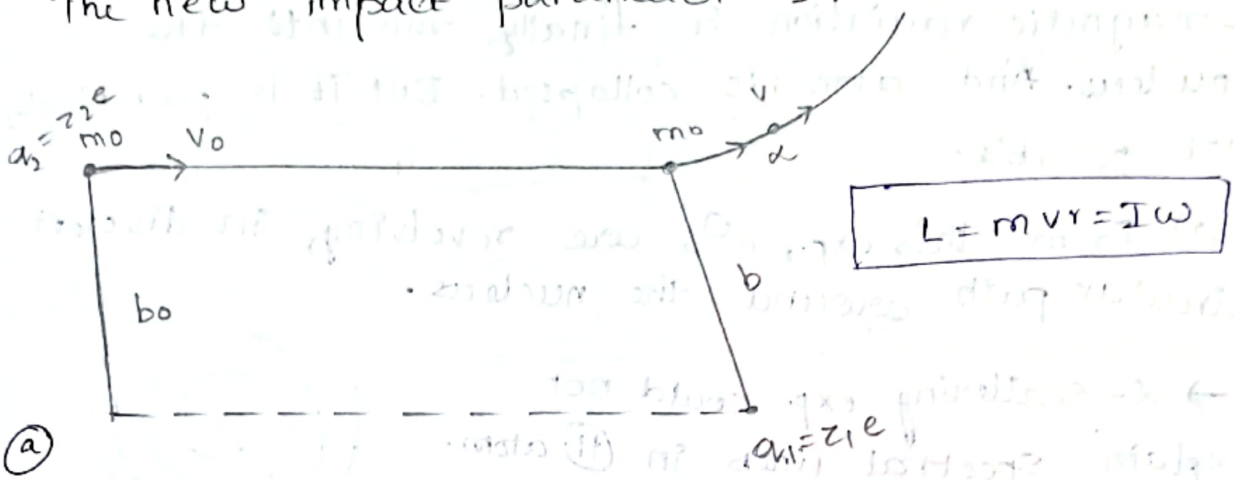
→ b is min. then angle of scattering max.

→ $b \propto \cot(\theta/2)$

→ $b \propto z$ (Atomic number).

* Application - ① :-

> An α-particle moving with initial velocity (V_0), impact parameter (b_0). When α-particle velocity becomes 'V'. The new impact parameter is :-



$$L = mvr = I\omega$$

(a)

Angular momentum

$$L_i = L_f$$

$$m_0 b_0 V_0 = m_0 b V$$

$$V = \frac{b_0 V_0}{b}$$

(b) According to conservation of energy.

$$(KE)_i = (KE + PE)_f$$

$$\frac{1}{2} m_0 V_0^2 = \frac{1}{2} m_0 V^2 + \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{b}$$

But $q_1 = ze$; $q_2 = 2e$.

$$\frac{1}{2} m_0 V_0^2 = \frac{1}{2} m_0 V^2 + \frac{1}{4\pi\varepsilon_0} \frac{2ze^2}{b}$$

$$V = b_0 V_0$$

$$\frac{1}{2} m_0 V_0^2 = \frac{1}{2} m_0 \frac{b_0^2 V_0^2}{b^2} + \frac{1}{4\pi\varepsilon_0} \frac{2ze^2}{b}$$

$$\frac{1}{2} m_0 V_0^2 \left[1 - \frac{b_0^2}{b^2}\right] = \frac{1}{4\pi\varepsilon_0} \frac{2ze^2}{b}$$

$$\epsilon \left[1 - \frac{b_0^2}{b}\right] = \frac{1}{4\pi\varepsilon_0} \frac{2ze^2}{b}$$

If $b_0 = 0$ then

$$\epsilon \left[1 - \frac{b_0^2}{b}\right] = \frac{1}{4\pi\varepsilon_0} \frac{2ze^2}{b} \Rightarrow \epsilon = \frac{1}{4\pi\varepsilon_0} \frac{2ze^2}{b}$$

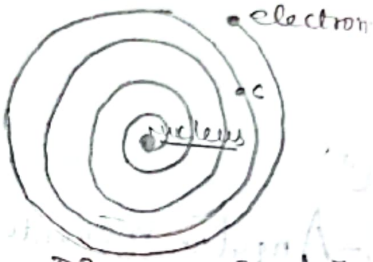
$$\therefore b = \frac{1}{4\pi\varepsilon_0} \frac{2ze^2}{\epsilon}$$

* Draw Backs:

① According to Rutherford's α-scattering exp., $e^{\ominus}$'s are revolving around the nucleus. It emitts electro-magnetic radiation & finally fall into the nucleus. And atom is collapsed. But it is practically not possible.

② From this exp., $e^{\ominus}$'s are revolving in discreet circular path around the nucleus.

→ α-scattering exp. could not explain spectral lines in (H) atom.



Discreat circular path.

30/07/2024:-(Tue):-

* BOHR's ATOMIC THEORY :-

> The Bohr proposed theory of hydrogen and (H) like atoms like: He^{+}, Li^{++}, Be^{+++} etc...

> According to bohr's atomic theory postulates

① Circular orbit.
② Bohr's quantum condition.
③ Bohr's Energy transition.

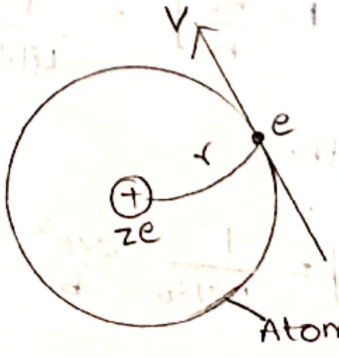
① CIRULAR ORBIT :-

> When $e^{\ominus}$'s revolving around the nucleus it doesn't emitts radiation.

> Coulomb's electrostatic force balanced by the centripetal force and centrifugal force.

According to coulomb's law:

$$F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$$



$$F = \frac{1}{4\pi\varepsilon_0}\frac{(ze)(e)}{r^2} \longrightarrow (1)$$

Centripetal force $(F) = \frac{mv^2}{r} \longrightarrow (2)$

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{ze^2}{r^2}$$

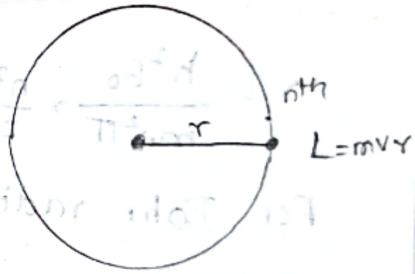
$$\boxed{mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{ze^2}{r}} \longrightarrow \text{I}^{st} \text{ postulate.}$$

For conservative force

$$\boxed{F = \frac{-dU}{dr} = \frac{mv^2}{r}}$$

(2) Bohr's Quantum rule :—

> When $e^\ominus$ revolving around the nucleus, the angular momentum of the $e^\ominus$ is equal to integral multiple of $\frac{h}{2\pi}$.



$$\boxed{\text{Angular momentum } L = n\left(\frac{h}{2\pi}\right)}$$

$$\boxed{\text{where } n = 1, 2, 3, \cdots}$$

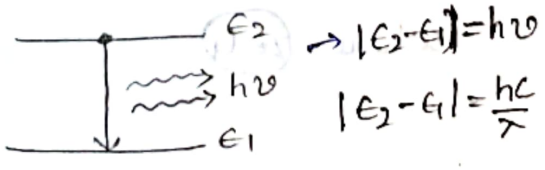
But $L = mvr$

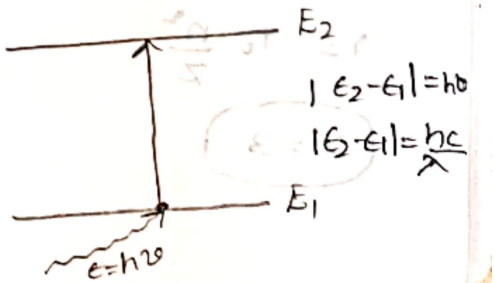
$$\boxed{mvr = n\frac{h}{2\pi}} \longrightarrow \text{II}^{nd} \text{ postulate.}$$

(3) Bohr's Energy Transition :—

> When $e^\ominus$ jump from higher energy level to lower energy level. It emitts radiation in the form of photon.

> The difference in energy levels is equal to energy of photon.



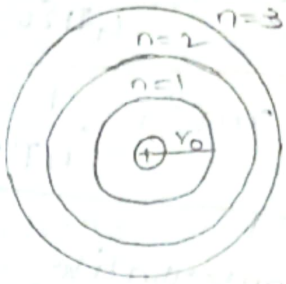


* RADIUS OF n^{th} ORBIT :-

> $mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{ze^2}{r} \rightarrow (1)$

But $mvr = n\frac{h}{2\pi}$

$v = \frac{nh}{2\pi mr} \rightarrow (2)$



$$m\left[\frac{nh}{2\pi mr}\right]^2 = \frac{1}{4\pi\varepsilon_0}\frac{ze^2}{r}$$

$$\frac{n^2h^2}{4\pi^2m^2r^2} = \frac{ze^2}{4\pi\varepsilon_0 \cdot r}$$

n^2, hi square, ε_0, mu, zee, pha

The radius of n^{th} orbit $(r) = \frac{n^2h^2\varepsilon_0}{mze e\pi}$ pacca bit

$$r = \frac{h^2\varepsilon_0}{me^2\pi} \times \frac{n^2}{z} = r_0\frac{n^2}{z}$$

For Bohr radius $r_0 = 0.53\,\text{Å}$

$$r = 0.53\frac{n^2}{z}$$

* Note :

(a) For H - Atom

$r = r_0\frac{n^2}{z}$

$z = 1$

(b) For He^+ Aton

$r = r_0\frac{n^2}{z}$

$z = 2$

(c) For Li^{++} Atom

$r = r_0\frac{n^2}{z}$

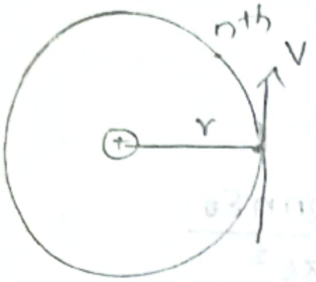
$z = 3$

(d) For Be^{+++} Atom

$r = r_0\frac{n^2}{z}$

where $z = 4$

* VELOCITY OF ELECTRON IN n^{th} ORBIT :-



We know

$$mvr = n\frac{h}{2\pi}$$

But radius of electron in n^{th} orbit

$$r = \frac{n^2h^2\varepsilon_0}{mZe^2\pi}$$

$$m\left[\frac{n^2h^2\varepsilon_0}{mZe^2\pi}\right]V = \frac{nh}{2\pi}$$

pacca Bit

$$V = \frac{Zee}{2nh\varepsilon_0}$$

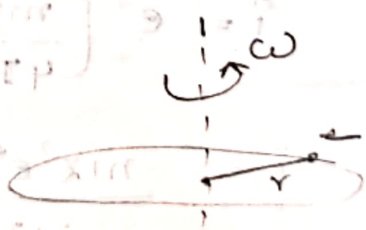
→ Zee TV 2 times National highway Ekkipoindi.

$$V = \left(\frac{e^2}{2h\varepsilon_0}\right)\frac{Z}{n} \Rightarrow V = V_0\left(\frac{Z}{n}\right)$$

$$V = 2.2\times10^6\left(\frac{Z}{n}\right) m/s \qquad V \propto \frac{Z}{n}$$

* Angular Velocity of electron in n^{th} orbit :-

Angular velocity $\omega = \frac{V}{r}$



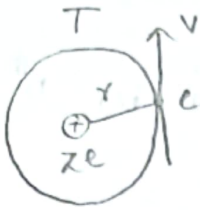
$$\omega = \frac{Zee}{2nh\varepsilon_0} \times \frac{me^2\pi}{n^2h^2\varepsilon_0}$$

$$\omega = \frac{mZ^2e^4\pi}{2n^3h^3\varepsilon_0^2}$$

$$\omega = \omega_0\frac{Z^2}{n^3} \Rightarrow \omega \propto \frac{Z^2}{n^3}$$

31/07/2024 (Wed).

* Time Period of $e^{\ominus}$ in n^{th} orbit :-



Time period (T) = $\frac{2\pi r}{v}$

$$T = \frac{2\pi n^2 h^2 \varepsilon_0}{mZe^2\pi} \times \frac{2nh\varepsilon_0}{Ze^2}$$

$$T = \frac{4\pi\varepsilon_0^2 n^3 h^3}{mZ^2 e\pi}$$

$$T = T_0 \frac{n^3}{Z^2}$$

$$\boxed{T \propto \frac{n^3}{Z^2}}$$ VVI

* Frequency of $e^{\ominus}$ in n^{th} orbit :-

$$\upsilon = \frac{1}{T} \Rightarrow \upsilon = \frac{mZ^2 e^4 \pi}{4\pi\varepsilon_0^2 n^3 h^3}$$

$$\boxed{\upsilon \propto \frac{Z^2}{n^3}}$$ VVI

* Electric Current (i) :-

Current (i) = $\frac{e}{T}$

$$i = e\left[\frac{mZ^2 e^4 \pi}{4\pi\varepsilon_0^2 n^3 h^3}\right]$$

$$i = \frac{mZ^2 e^4 \times e}{4n^3 h^3 \varepsilon_0^2}$$

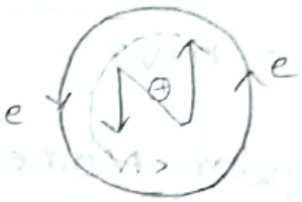
$$i = \frac{mZ^2 e^5}{4n^3 h^3 \varepsilon_0^2}$$

$$i = i_0 \frac{Z^2}{n^3}$$

$$\boxed{i \propto \frac{Z^2}{n^3}}$$

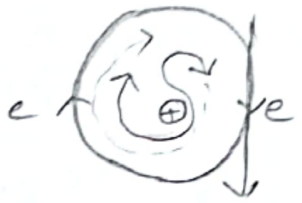
* Magnetic field due to electron :-

$$B = \frac{\mu_0 i}{2r}$$



$$B = \frac{\mu_0 m z^2 e^5}{4\varepsilon_0^2 n^3 h^3} \times \frac{1}{2} \times \frac{mze^2\pi}{n^2 h^2 \varepsilon_0}$$

$$B = \frac{\mu_0 m^2 z^3 e^7 \pi}{8\varepsilon_0^3 n^5 h^5}$$



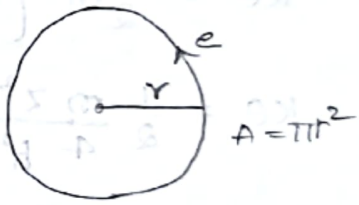
$$B = B_0 \frac{z^3}{n^5}$$

$$B \propto \frac{z^3}{n^5}$$ ✓

* Magnetic dipole Movement due electron :-

$$M = iA$$

$$M = i\pi r^2$$



Magnetic dipole movement

$$M = \frac{\pi m z^2 e^5}{4\varepsilon_0^2 n^3 h^3} \times \left[\frac{n^2 h^2 \varepsilon_0}{mze^2\pi}\right]^2$$

$$M = \frac{\pi m z^2 e^5}{4\varepsilon_0^2 n^3 h^3} \times \frac{n^4 h^4 \varepsilon_0^2}{m^2 z^2 e^4 \pi^2}$$

$$M = n\left(\frac{he}{4\pi m}\right)$$

$$M \propto n$$

* Linear momentum of $e^\ominus$ in n^{th} orbit :-

$$p = mv$$

Linear momentum (p) $= m\left[\frac{ze^2}{2nh\varepsilon_0}\right]$

$$p = \left[\frac{me^2}{2h\varepsilon_0}\right]\left(\frac{z}{n}\right)$$

$$p \propto \frac{z}{n}$$

* Angular Momentum (L) :-

$$L = mvr$$

Angular Momentum $(L) = \frac{mZe^2}{2\pi h \varepsilon_0} \times \frac{n^2 h^2 \varepsilon_0}{mZe^2\pi}$

$$\boxed{L = n\left(\frac{h}{2\pi}\right)}$$

$$\boxed{L \propto n}$$

(VVI) pacca (1) Q.

* Kinetic energy of electron in n^{th} orbit :-

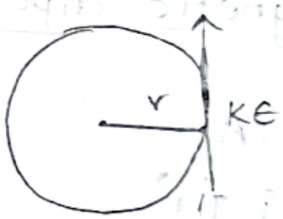
$$KE = \frac{1}{2}mv^2$$

$$KE = \frac{1}{2}m\left[\frac{Zee}{2nh\varepsilon_0}\right]^2$$

$$KE = \frac{1}{2}\frac{mZ^2e^4}{4h^2n^2\varepsilon_0^2}$$

$$KE = \left(\frac{me^4}{8h^2\varepsilon_0^2}\right)\frac{Z^2}{n^2}$$

$$\boxed{KE = 13.6\left(\frac{Z^2}{n^2}\right) eV}$$



① For (H) atom

$Z = 1$

$$\boxed{KE = \frac{13.6}{n^2} eV}$$

② For (He^+) atom

$Z = 2$

$$KE = \frac{13.6}{n^2} \times 4$$

$$\boxed{KE = \frac{54.4}{n^2} eV}$$

③ For Li^{++} atom

$Z = 3$

$$KE = \frac{13.6}{n^2} \times 9$$

$$\boxed{KE = \frac{122.4}{n^2} eV}$$

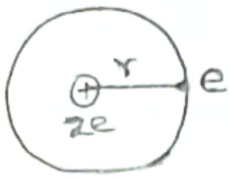
④ for Be^{+++} atom.

$Z = 4$

$$KE = \frac{13.6}{n^2} \times 16$$

$$\boxed{KE = \frac{217.6}{n^2} eV}$$

* Potential energy of $e^{\ominus}$ in n^{th} orbit :-



$$U = -\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$

$$U = -\frac{1}{4\pi\varepsilon_0}\frac{(Ze)e}{n^2h^2\varepsilon_0} \times m Z e^2 \pi$$

Potential Energy (PE) $= U = -\left(\frac{me^4}{4h^2\varepsilon_0^2}\right)\frac{Z^2}{n^2}$

$$U = -27.2\,\frac{Z^2}{n^2}\ eV$$

① For (H) atom

$Z = 1$

$$U = -\frac{27.2}{n^2}\ eV$$

② For He^+ atom

$Z = 2$

$$U = \frac{-108.8}{n^2}\ eV$$

③ For Li^{++} atom

$Z = 3$

$$U = -\frac{27.2}{n^2} \times 9$$

$$U = -\frac{244.8}{n^2}\ eV$$

④ For Be^{+++} atom

$Z = 4$

$$U = -\frac{27.2}{n^2} \times 16$$

$$U = -\frac{435.2}{n^2}\ eV$$

* Total Energy of electron in n^{th} orbit :-

$$TE = PE + KE$$

$$TE = -\left(\frac{me^4}{4h^2\varepsilon_0^2}\right)\frac{Z^2}{n^2} + \left(\frac{me^4}{8h^2\varepsilon_0^2}\right)\frac{Z^2}{n^2}$$

$$TE = -\left(\frac{me^4}{8h^2\varepsilon_0^2}\right)\frac{Z^2}{n^2}$$

$$TE = -13.6\,\frac{Z^2}{n^2}\ eV$$

① For (H) atom

$Z = 1$

$$TE = -\frac{13.6}{n^2}\ eV$$

② For He^+ atom

$Z = 2$

$$TE = -\frac{13.6}{n^2} \times 4$$

$$TE = -\frac{54.4}{n^2}\ eV$$

③ For $Be Li^{++}$ atom

$Z = 3$

$$TE = -\frac{13.6}{n^2} \times 9\ eV$$

$$TE = -\frac{122.4}{n^2}\ eV$$

④ For Be^{+++} atom

$Z = 4$

$$TE = -\frac{13.6}{n^2} \times 16$$

$$TE = -\frac{217.6}{n^2}\ eV$$

* previous Jee (Q) (Fixed Answer)

(Q) The ratio of TE, KE and PE is :-

$$TE : KE : PE = -13.6\,\frac{Z^2}{n^2} : 13.6\,\frac{Z^2}{n^2} : -27.2\,\frac{Z^2}{n^2}$$

$$TE : KE : PE = -1 : 1 : -2$$

(for same element).

(Q) When $e^{\ominus}$ revolving in first orbit the total energy $-20eV$. Find KE of the $e^{\ominus}$ and PE of the $e^{\ominus}$

$KE = -TE$

$KE = -(-20eV)$

$KE = 20eV$

$PE = 2.TE$

$PE = -2(20)\ eV$

$PE = -40eV$

* Energy levels :-

→ When $e^{\ominus}$ jumps from higher energy level to lower energy level it emitts radiation in the form of spectral lines. It is divide into different catogiries like:

1. Lyman series
2. Balmer series
3. paschen series
4. Brackett series
5. P-fund series.
6. Humphery series.

① LYMAN SERIES :- Every year (Q).

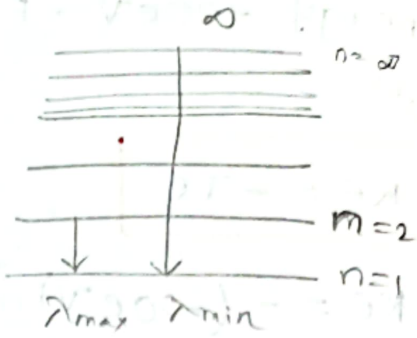
→ When $e^{\ominus}$ jumped from higher energy levels (n_2) is $2,3,4,5,\cdots$ to lower energy level $(n_1) = 1$.

→ It emitts spectral lines are called lyman series.

→ It belongs to U.V region.

→ It is not visible.

* For maximum wave length :-



$n_1 = 1 \quad ; \quad n_2 = 2$

$$\frac{1}{\lambda} = R Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda} = R (1)^2 \left[\frac{1}{1} - \frac{1}{4}\right]$$

$$\boxed{\lambda = \frac{4}{3R} \text{ A}^\circ}$$

$(R = 1.109 \times 10^7/m)$

* For minimum wave length :-

$n_1 = 1 \quad ; \quad n_2 = \infty$

$$\frac{1}{\lambda} = R Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda} = R (1)^2 \left[\frac{1}{1} - 0\right] \Rightarrow \boxed{\lambda = \frac{1}{R} \text{ A}^\circ}$$

(2) BALMER SERIES :-

→ When e^Θ jumped from s higher energy levels $(n_2) = 3, 4, 5, \ldots$ to lower energy levels $n_1 = 2$ It emitts spectral lines are called Balmer Series

→ It belongs to visible region

* For max. wave length :-

$n_1 = 2 \quad ; \quad n_2 = 3$

$$\frac{1}{\lambda} = R Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda} = R(1)^2 \left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\frac{1}{\lambda} = R\left(\frac{5}{36}\right) \qquad \boxed{\lambda = \frac{36}{5R} A^\circ}$$

* For minimum wave length :-

$$n_1 = 2 \; ; \quad n_2 = \infty$$

$$\frac{1}{\lambda} = R z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda} = R(1)^2 \left(\frac{1}{4} - \frac{1}{\infty}\right] \qquad \frac{1}{\lambda} = R\left(\frac{1}{4}\right)$$

$$\boxed{\lambda = \frac{4}{R} A^\circ}$$

(3) PASCHEN SERIES :-

→ When $e^\ominus$ jumps from higher energy levels $n_2 = 4, 5, 6, \ldots$ to lower energy level $\boxed{n_1 = 3}$.

It emitts spectral lines are called Paschen Series.

→ It belongs to Infra-Red region (I.R region).

→ It is not visible.

→ It is near to visible region.

* For maximum wave length :-

$$n_1 = 3 \; ; \quad n_2 = 4$$

$$\frac{1}{\lambda} = R z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda} = R(1)^2 \left[\frac{1}{9} - \frac{1}{16}\right]$$

$$\frac{1}{\lambda} = R\left(\frac{7}{144}\right) A^\circ \qquad \boxed{\lambda = \frac{144}{7R} A^\circ}$$

* For minimum wave length :-

$n_1 = 3$; $n_2 = \infty$

$$\frac{1}{\lambda} = R(z)^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{\lambda} = R(1)^2 \left[\frac{1}{9} - 0\right]$$

$$\boxed{\lambda = \frac{9}{R} A^\circ}$$

④ BRACKETT SERIES :-

→ When $e^\ominus$ jumps from higher energy levels $n_2 = 5, 6, 7, \ldots$ to lower energy level $n_1 = 4$. It emitts spectral lines are called Brackett series

→ It belongs to Infra-Red region (I.R region)

→ It

- For Max. wave length :-

$n_1 = 4$; $n_2 = 5$

$$\frac{1}{\lambda} = R(z)^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R(1)^2 \left(\frac{1}{16} - \frac{1}{25}\right)$$

$$\boxed{\lambda = \frac{400}{9R} A^\circ}$$

- For Min. wave length :-

$n_1 = 4$; $n_2 = \infty$

$$\frac{1}{\lambda} = R(1)^2 \left(\left(\frac{1}{16}\right) - 0\right)$$

$$\boxed{\lambda = \frac{16}{R} A^\circ}$$

⑤ P-Fund SERIES:

→ When $e^{\ominus}$ jumped from higher energy levels $n_2 = 6, 7, 8 \ldots$ to lower energy level $n_1 = 5$ it emitts spectral lines called p-fund series

→ Belongs to Infra-Red region

But very far distance from visible region.

• For Max. wave length :

$n_1 = 5 \quad n_2 = 6$

$\frac{1}{\lambda} = R(1)^2 \left(\frac{1}{25} - \frac{1}{36}\right)$

$\frac{1}{\lambda} = R\left(\frac{11}{900}\right) A^\circ$

$\lambda = \frac{900}{11R} A^\circ$

• For Min. wave length:

$n_1 = 5 \quad n_2 = \infty$

$\frac{1}{\lambda} = R(1)^2 \left(\frac{1}{25} - 0\right)$

$\lambda = \frac{25}{R} A^\circ$

⑥ HUMPHERY SERIES:

→ When $e^{\ominus}$ jumped from higher energy levels $n_2 = 7, 8, 9, \ldots$ to lower energy level $n_1 = 6$ it emitts spectral lines are called Humphery Series.

→ It belongs to Infra-red region. But very close to Micro waves.

Used in lights of aeroplanes for indicating.

• For Max wave length

$n_1 = 6 \quad n_2 = 7$

$\frac{1}{\lambda} = R(1)^2 \left(\frac{1}{36} - \frac{1}{49}\right)$

$\frac{1}{\lambda} = R\left(\frac{13}{1764}\right) A^\circ$

$\lambda = \frac{1764}{13} A^\circ$

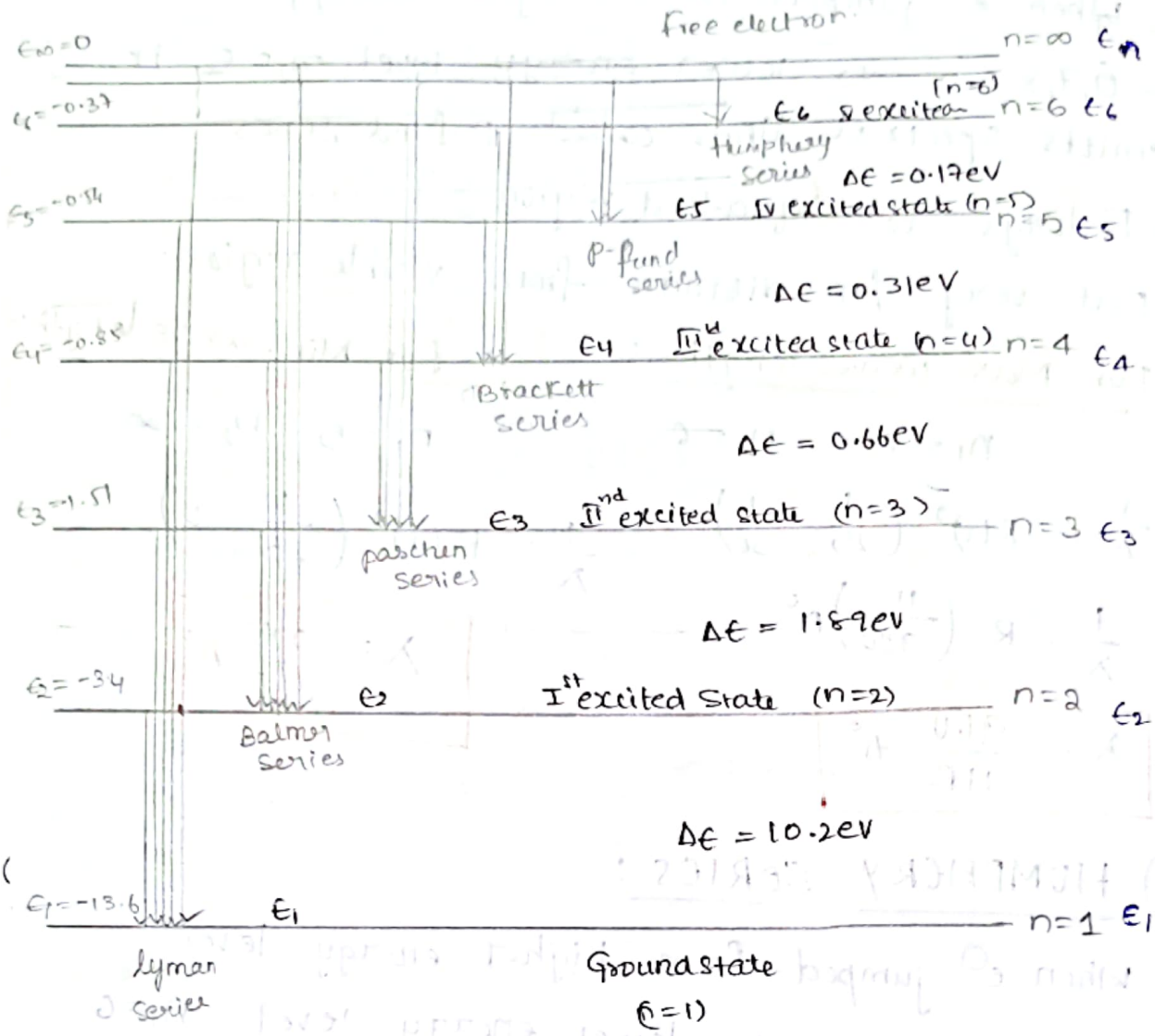
• for Min wave length:

$n_1 = 6 \quad n_2 = \infty$

$\frac{1}{\lambda} = R(1)^2 \left(\frac{1}{36} - 0\right)$

$\lambda = \frac{36}{R} A^\circ$

* HYDROGEN SPECTRAL LINES :-



$\epsilon_n = 0\ eV$

$\epsilon_1 = \frac{-13.6\,z^2}{n^2} = \frac{-13.6\,(1)}{(1)}$

$\epsilon_2 = -\frac{13.6}{(2)^2}\frac{(1)^2}{} = -3.4\,z^2\,eV$

$\epsilon_3 = \frac{-13.6}{3^2} = -1.51\,z^2\,eV$

$\epsilon_4 = \frac{-13.6}{4^2} = -0.85\,z^2\,eV$

$\epsilon_5 = \frac{-13.6}{5^2} = -0.54\,z^2\,eV$

$\epsilon_6 = \frac{-13.6}{6^2} = -0.37\,z^2\,eV$

MAINS

* IONIZATION ENERGY :-

> The minimum amount of energy required to move the $e^{\ominus}$ from lower energy level to '∞' level is called Ionization Energy.

Ex: Let an $e^{\ominus}$ revolving in first orbit the ionization energy is $+13.6\ eV$

Note :

Ionization potential : The min. amount of potential required to move the $e^{\ominus}$ from lower energy level or ground state to ∞ is called Ionization potential.

Ex: When $e^{\ominus}$ revolving at ground state the ionization potential

$$V = \frac{\Delta E}{e}$$

$$V = \frac{+13.6\ eV}{e} \Rightarrow V = +13.6\ V$$

* DEBROGLIE EXPLANATION FOR BOHR'S QUANTUM RULE :-

According to debroglie explanation, the $e^{\ominus}$ revolving around the nucleus the total angular momentum remains constant.

Debroglie wavelength $(\lambda) = \frac{h}{p} \rightarrow (1)$

for n^{th} orbit

$$n\lambda = 2\pi r$$

$$n \times \frac{h}{p} = 2\pi r$$

$$\frac{nh}{2\pi} = pr$$

$$n\lambda = 2\pi R$$

$$n\lambda = 2\pi r$$

$$\frac{nh}{2\pi} = mvr \qquad (p = mv)$$

Angular momentum $L = mvr$

$$\therefore \; L = \frac{nh}{2\pi}$$

Important Models :-

(1) * When $e^{\ominus}$ jump from n^{th} orbit to first orbit the total no. of spectral lines $N = \frac{n(n-1)}{2}$ → Ans.

(It follows nC_2 rule).

$n_2 = 2, 3, 4 \cdots$

$n_1 = 1$

* When $e^{\ominus}$ jumped from 5^{th} orbit to 2^{nd} orbit the total no. of Spectral lines

$$N = \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

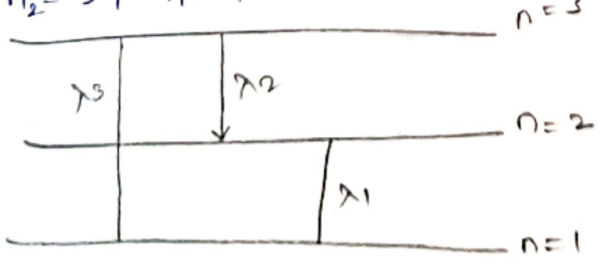
Ex: $n_2 = 5, \; n_1 = 2$

$$N = \frac{(5-2)(5-2+1)}{2} = \frac{3 \times 4}{2} = 6.$$

Exc

* When $e^{\ominus}$ jumps from 3^{rd} orbit to 1^{st} orbit. The total no. of spectral lines.

$n_2 = 3, \; n_1 = 1$



$N = \frac{n(n-1)}{2}$

$N = \frac{3(3-1)}{2} = 3$

$\rightarrow \frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

$\rightarrow E_3 = E_1 + E_2$

01/05/2024 (Thu) :-

* A graph drawn b/w energy on y-axis, distance on x-axis. The nature of the graph is :-

* $V = \frac{ze^2}{2nh\varepsilon_0} \Rightarrow V = \left(\frac{e^2}{2h\varepsilon_0}\right) \times \frac{z}{n}$

$\hookrightarrow \boxed{V = \left(\frac{c}{137}\right) \times \frac{z}{n}}$

* When $e^\ominus$ revolving in n^{th} orbit the speed of the $e^\ominus$ is :- $V = \left(\frac{c}{137}\right) \times \frac{z}{n}$

$c = 3 \times 10^8 m/s$

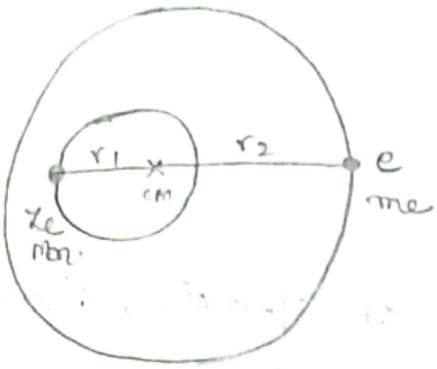
$\boxed{V = 2.2 \times 10^6 \frac{z}{n}}$

Adv

* The Effect of Nucleus mass on Bohr Model :-

> If nucleus not at centre. and $e^\ominus$'s, ~~nucl~~ nucleus revolving around centre of mass of the system. Then effective mass of the system reduced it is called Reduced mass.

> It is represented by 'μ'.



Mass x distance = constant

$$m_n r_1 = m_e r_2$$

Here :- $\boxed{r = r_1 + r_2}$

$$\boxed{r_2 = r - r_1}$$

$$m_n r_1 = m_e (r - r_1)$$

$$r_1 \cdot (m_n + m_e) = m_e r \rightarrow (1)$$

The distance from centre of mass to nucleus

$$\boxed{r_1 = \left(\frac{m_e}{m_n + m_e}\right) r}$$ (Based on (1)).

The distance from centre of mass to $e^{\ominus}$

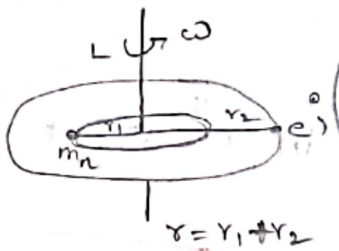
$$\boxed{r_2 = \left(\frac{m_n}{m_n + m_e}\right) r}$$

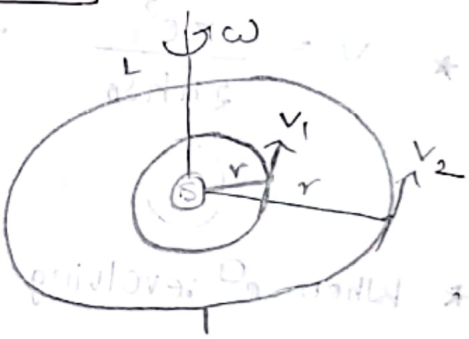
Case (1):

We know that,

$$L = n\frac{h}{2\pi}$$

$$m v_1 r_1 = n\frac{h}{2\pi}$$





$\boxed{V = \omega r}$

$\boxed{\omega_1 = \omega_2 = \omega}$

$$m_n r_1 \omega r_1 = n\frac{h}{2\pi}$$

$$m_n r_1^2 \omega = n\frac{h}{2\pi} \Longrightarrow \boxed{m_n \left[\frac{m_e r}{m_n + m_e}\right]^2 \omega = \frac{nh}{2\pi}}$$

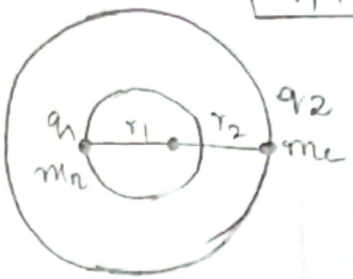
★ **Note:** $L = n\frac{h}{2\pi}$

$$m_e r_2 v = n\frac{h}{2\pi} \Rightarrow \boxed{m_e r_2^2 \omega = \frac{nh}{2\pi}}$$

Case-(2):

→ Backside.

* case-② :-



$$F = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)e}{r^2} \longrightarrow ①$$

$$F = \frac{m_n v^2}{r_1} = \frac{m_n r_1^2 \omega^2}{r_1} = m_n r_1 \omega^2 \quad \hookrightarrow ②$$

$$\boxed{v = r\omega}$$

① = ②

$$m_n r_1 \omega^2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2}{r^2}$$

$$m_n\left[\frac{m_e r}{m_n+m_e}\right]\omega^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2}$$

$$m_n\left[\frac{m_e}{m_n+m_e}\right] r^3\omega^2 = \frac{1}{4\pi\varepsilon_0} Ze^2$$

$$\boxed{\mu r^3\omega^2 = \frac{1}{4\pi\varepsilon_0} Ze^2}$$

* Please note when nucleus is at rest. The effective mass taken as mass of $e^{\ominus}$. If nucleus & $e^{\ominus}$s are revolving about the centre of mass the effective mass is $\mu = \frac{m_n m_e}{m_n+m_e}$.

* Where $\boxed{\mu}$ ⟶ Reduced mass of the system.

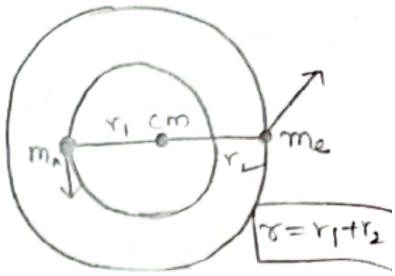
* App-① :-

The mass of the nucleus (m_n) and mass of $e^{\ominus}$ (m_e) are revolving about the centre of mass. Find radius of n^{th} orbit for (H) like atom.

For nucleus at rest

$$r_n = \frac{n^2h^2\varepsilon_0}{m_e Ze e^2\pi}$$

for nucleus & $e^{\ominus}$ revolving about centre of mass.



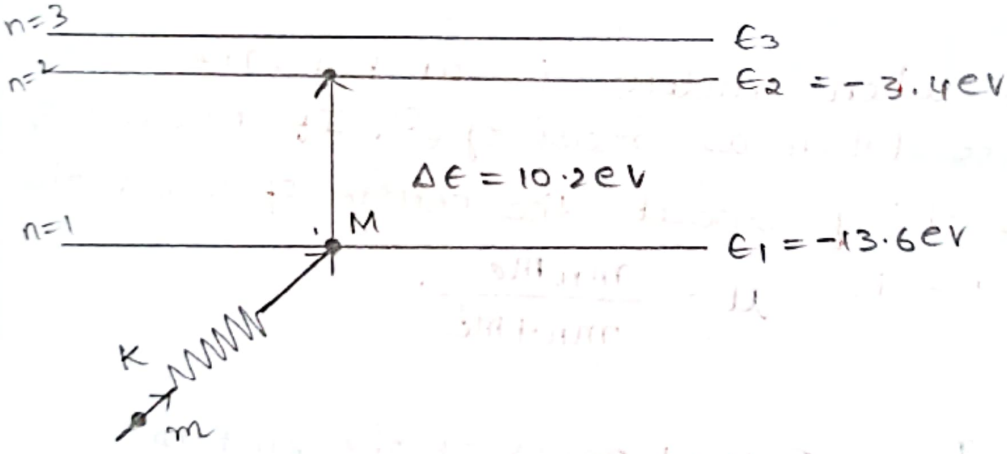
$$r = \frac{n^2 h^2 \varepsilon_0}{\mu z e^2 \pi}$$

Where reduced mass $(\mu) = \dfrac{m_e m_n}{m_e + m_n}$

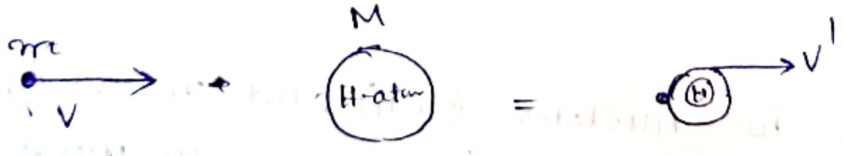
* ELECTRON COLLISION :-

› Let a particle of mass (m) moving with velocity (v). It is collide with stationary (H) like atom of mass (M) at ground state.

① case - ① :-



Inelastic collision



$$mv = (m+M)\,v'$$

$$v' = \frac{mv}{m+M}$$

For max. loss of energy :-

$$\Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}(m+M)(v')^2$$

$$\Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}(m+M)\frac{m^2v^2}{(m+M)^2}$$

$$\Delta KE = \frac{1}{2}mv^2\left[1 - \frac{m}{(M+m)}\right]$$

Max loss $\Delta KE = KE_i\left[1 - \frac{m}{M+m}\right]$ (Inelastic collision)

* Case - (2) :

Min. loss $\Delta KE = 0$ (elastic collision)

* Note :

Range :- $0 < \Delta E < \frac{1}{2}\left(\frac{m_1 m_2}{m_1+m_2}\right)(u_1-u_2)^2$

* Note :-

* If maximum loss of energy $\Delta KE < E_2 - E_1$

$$\Delta KE < 13.6\, z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

→ Then no excited ~~electron~~ to higher levels.

* If max loss of energy $\Delta KE \geq E_2 - E_1$

$$\Delta KE \geq 13.6\, z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

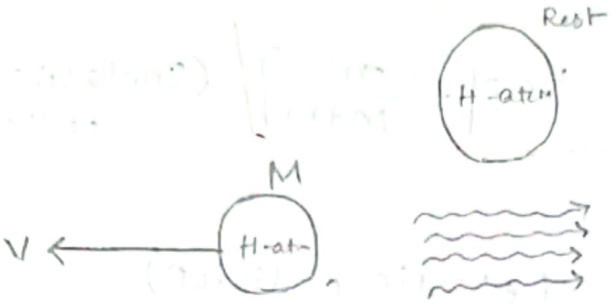
Then $e^{\ominus}$'s excited to higher levels.

(Eg)

* RECOIL OF ATOM DUE TO ELECTRON EMISSION :-

> The (H) atom is recoiled due to emission of photon.

> According to law of conservation of momentum,



$p \rightarrow$ momentum

$$0 = |P_H| + |P_{photon}|$$

$$\boxed{P_H = P_{photon}}$$

$$\therefore P_H = P_{photon}$$

$$MV = \frac{\Delta E}{c} \quad \left[\because P = \frac{E}{c}\right]$$

$$MV = \frac{E_f - E_i}{c}$$

$$\boxed{\text{Recoil speed } V = \frac{E_f - E_i}{MC}}$$

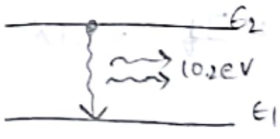
Where $\Delta E = E_f - E_i$

$$\Delta E = 13.6 Z^2 \left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]$$

Ex: $n_1 = 1$; $n_2 = 2$; $Z = 1$

$$\boxed{\Delta E = 10.2 eV}$$

$$V = \frac{\Delta E}{M_H C}$$



$$\boxed{V_H = \frac{10.2}{M_H C} eV}$$

(Q) The potential energy b/w $e^{\ominus}$ and proton is $U = K\left(\log_e^r - \frac{1}{2}\right)$, where K is constant. Calculate radius of the n^{th} orbit & Energy level.

$$U = K\left(\log e^r - \frac{1}{2}\right)$$

(A)

$$F = -\frac{dU}{dr}$$

$$F = -K \frac{d}{dr}(\log_e r) + K \frac{d}{dr}\left(\frac{1}{2}\right)$$

$$F = -K \times \frac{1}{r} + 0$$

$$|F| = \left|-\frac{K}{r}\right| \Rightarrow \boxed{F = \frac{K}{r}}$$

$$F = \frac{K}{r} \Rightarrow \frac{mv^2}{r} = \frac{K}{r} \Rightarrow \boxed{K = mv^2}$$

$$mvr = \frac{nh}{2\pi}$$

But $\boxed{mv^2 = K} \Rightarrow \boxed{v = \sqrt{\frac{K}{m}}}$

$$r\sqrt{\frac{K}{m}} \cdot r = \frac{nh}{2\pi} \Rightarrow r\sqrt{Km} = \frac{nh}{2\pi}$$

$$\boxed{r = \frac{nh}{2\pi\sqrt{Km}}}$$

(B) $\boxed{TE = PE + KE}$

$$TE = K(\log_e r - \frac{1}{2}) + \frac{1}{2}mv^2$$

But $\boxed{mv^2 = K}$

$$TE = K(\log_e r) - \frac{K}{2} + \frac{1}{2}K \Rightarrow \boxed{TE = K(\log_e r)}$$

(Q) A small particle of mass (m) is moving with PE $(U) = -\frac{1}{2}mb^2r^2$, where b is constant & r is distance from the origin taken at nucleus. Find n^{th} orbit radius is

$$F = -\frac{dU}{dr}$$

$$F = -\frac{d}{dr}\left(-\frac{1}{2}mb^2r^2\right)$$

$$F = \frac{d}{dr}(r^2) \cdot \frac{1}{2}mb^2$$

$$F = \frac{1}{2}mb^2 \times 2r$$

$$\boxed{F = mb^2r}$$

$$mvr = n\frac{h}{2\pi} \qquad F = mb^2 r$$

$$r = \frac{F}{mb^2} \qquad r = ma$$

$$mv\left(\frac{F}{mb^2}\right) = n\frac{h}{2\pi}$$

$$\frac{2\pi\,(mv)\left(\frac{F}{mb^2}\right)}{h} = n$$

$$\frac{2\pi\,\frac{F}{vb^2}}{h} = n \Longrightarrow n = \frac{2\pi F}{mvb^2}$$